



Foundational and Systems Support for Quantitative Trust Management (QTM)

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Project Team

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 Real-time and cyber-physical systems, Run-time monitoring
- Matt Blaze (Ph.D. 93, Princeton)
 Network security, Cryptography, Trust Management
- Oleg Sokolsky (Ph.D. 96, SUNY-SB)
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Trust

- Webster"s Dictionary: TRUST, -noun:
 - (1) Assured reliance on the character, ability, strength, or truth of someone or something.
 - (2) One in which confidence is placed.

Our Definition:

 Trust is the expectation of a trustor with respect to certain properties of a trustee or her actions under a specified context and time, considering the risks, incentives, and historical information.



The Problem of Trust

- Quantitative Trust for federated networked systems
 - Decentralized policies
 - Dynamic environment, partial trust
 - Complex "trust" models (logic + reputation), in reality



Applications

- E-commerce systems
- Service compositions in GIG
- Reusing components/subsystem in complex DoD systems
- Social Networks

Medical systems

Cloud computing





Trust Management

Policy-Based Trust Mgmt. (PTM)

- Effective for delegated credentials and access enforcement
- Can't handle uncertainty and partial information

Rep-Based Trust Mgmt. (RTM)

- Quantifies trust relationships
- No delegation (i.e., reputation no-transferable)
- No enforcement

QUANTITATIVE TRUST MANAGEMENT (QTM)

- Combine PTM and RTM
- Dynamic interpretation of authorization policies for access control decisions based on upon evolving reputations of the entities involved





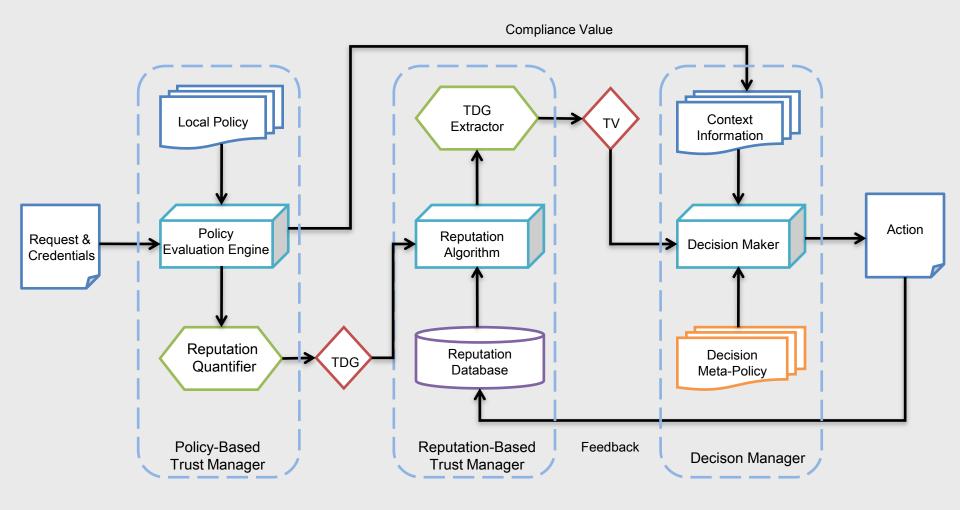
QTM Challenges

- What are some metrics for effectiveness of TM systems?
- How do we incorporate uncertainty in policy-based TM"s?
- How do we incorporate dynamism in policy-based TM"s?
- How can we model adversaries as economic agents and develop a game-theoretic view of trust management?
- Can we build new reputation management systems based on sound principles?
- What is the proper way to mathematically combine reputations?
 - Involves integration of logical/quantitative/probabilistic reasoning
 - Is there a means to build consensus from distributed observations?
- How do we integrate policy-based and reputation-based TMs?
- What are some important applications of TM systems?





Quantitative Trust Management (QTM)







Collaboration



Policy-based Trust Management (PTM)









11/4/09

KeyNote PTM Systems

Permission-to-Speak

Dynamic Trust Management Arachne





Collaboration









Reputation-based Trust Management (RTM)





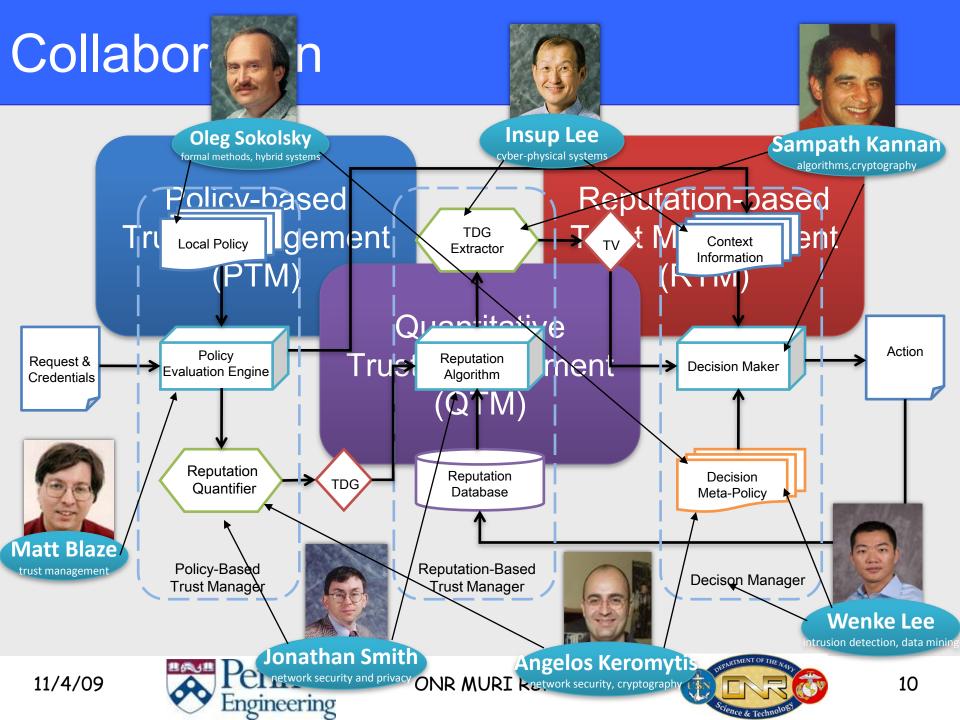
Evaluating RTM Systems

Blacklist as Feedback of Reputation Management









Team Efforts

- Several Research Collaborations
 - Distributed TM, Dynamic TM, Spatio-Temporal Reputations, ...
 - Keynote-base QTM
- Annual meetings
 - 2007, 2008, 2009
- Many Tele-conferences and Student Visits
 - Penn -> GA Tech, Columbia -> Penn, GA Tech -> Penn
- Collaborative case studies
 - SPAM list and BGP security as QTM application
- PhD Dissertation Committees
 - Matt Burnside (Columbia)
 - David Dagon (GA Tech)
 - Andrew West (Penn)





Education

Courses

- Integrated material into COMS W4180 course (Columbia)
- CIS 125 new course on understanding of existing and emerging technologies, along with the political, societal and economic impacts of those technologies (Penn)
- Integrated material into CIS 551 (Penn)
- Material on botnet detection added to Network Security classes: undergraduate cs4237, and graduate cs6262 (GA Tech)
- 3 senior design projects (Penn)

Workforce training

- 3 post-docs
- 10 Ph.D. students
- 1 Masters and 1 undergraduate





Publication

Publications

- 7 journal articles
- 2 book chapter
- 33 conference papers

Selected papers

- M. Blaze, S. Kannan, I. Lee, O. Sokolsky, J.M. Smith, A.D. Keromytis, and W. Lee.
 Dynamic Trust Management, In IEEE Computer Magazine, vol. 42, no. 2, pp. 44 52, February 2009.
- A.G. West, A.J. Aviv, J. Chang, V. Prabhu, M. Blaze, S. Kannan, I. Lee, J.M. Smith, and O. Sokolsky. QuanTM: A Quantitative Trust Management System. EUROSEC 2009, pp. 28-35.
- A.G. West, I. Lee, S. Kannan, and O. Sokolsky. An Evaluation Framework for Reputation Management Systems. In *Trust Modeling and Management in Digital Environments: From Social Concept to System Development* (Zheng Yan, ed.), 2009.

Dissemination & Tech transfer

- Beyond conference talks
 - 7 invited and 2 keynote talks, 6 panels
- Working with Symantec to determine modus operandi of rogue Antivirus sites (and why users trust them)
 - Interim Symantec Threat Report (ISTR), Oct 09
- Working with Damballa to deliver botnet detection and mitigation technologies to government and enterprise customers
 - Botnet detection system such BotMiner malware analysis technologies, and the DNS-based monitoring technologies
 - Several Ph.D. students did summer internship
 - Several Damballa researchers were former students at Georgia Tech, and still participate in some of the research meetings at Georgia Tech
- Matt Burnside now working for NSA
- QTM ideas used in ONR-supported "Networks Opposing Botnets" (NoBot) project, withPenn, Harvard and Princeton





Research highlights

- Project Overview, Insup Lee (PI)
- Trust Management, Matt Blaze
- Dynamic Trust Management, Jonathan M. Smith
- Exposing Trust Assumptions in Distributed Policy Enforcement, Angelos Keromytis
- Permission to Speak: A Novel Formal Foundation for Access Control, Oleg Sokolsky
- Dynamic IP Reputation from DNS, Wenke Lee
- Using Spatiotemporal Reputation to Predict Malicious Behaviors, Andrew West
- Reputations and Games, Sampath Kannan
- Future Work and Discussion, Insup Lee

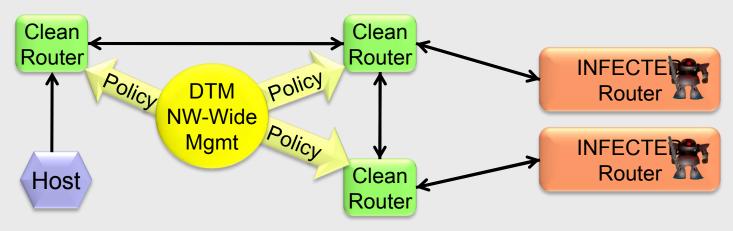




Dynamic Trust Management

(Penn + Columbia + Georgia Tech)

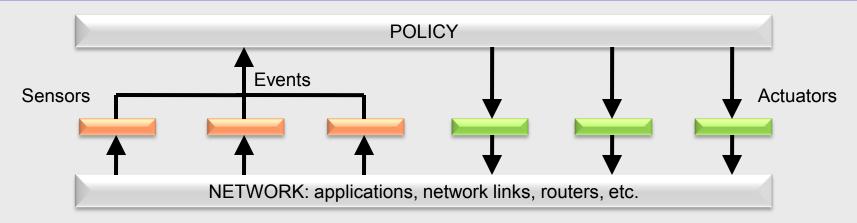
- A COOPERATIVE and DYNAMIC policy evaluation infrastructure that will enable such critical capabilities as:
 - Adaptation to dynamic service availability
 - Complex situational dynamics (e.g., differentiating between bot-net and physical attacks on infrastructure).
- BENEFITS of a Dynamic Trust Management approach
 - Flexible and robust control of authorizations in complex distributed systems such as the DoD/IC GIG
 - The ability to define policies for scalable decentralized defense against emergent cyber-threats by rapid adaptation of resource access limits.





Arachne: Coordinated Policy Enforcement

Columbia)



- ARACHNE is a system for the coordinated distribution and evaluation of a system-wide policy on different nodes
 - Several prototype systems for enterprise-level security have been developed
- GOAL: Integrate a variety of different, diverse security mechanisms and policy expression methods
 - Achieve enhanced protection over any individual method
 - Allow exchange of information between different mechanisms (Eliminate the possibility of "locally correct" but globally wrong decisions
 - Capture trade-offs between amount of global context, scalability, etc.





Permission-to-Speak

- A new policy deontic logic developed under ONR-MURI
- Explicit representation of PERMISSIONS and OBLIGATIONS imposed by a policy, and the delegation of policies.
 - Captures notions such as "allow to require" which are necessary for dynamic policy introduction.
- Explicit representation of policy DEPENDENCIES
 - Iterative algorithm for calculating the set of relevant policy statements
- Logic prog.-based evaluation allows efficient blame assignment

 $P_{\text{pat}} \text{ says}_{\text{pat}} O_{\text{hosp}} \text{ says}_{\text{hosp}} P_{\text{pat}} \text{ access(pat, record(pat))}$



Patients are allowed to ask a hospital for their medical records. In response, the hospital must permit access.

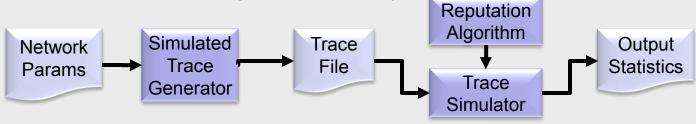


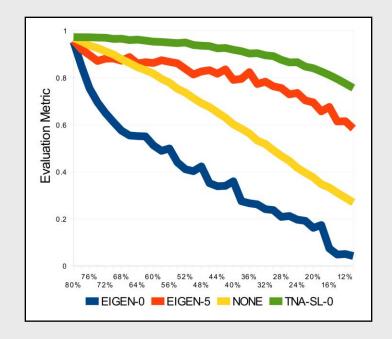


Evaluating RTM Systems

- Many reputation systems are available in the literature
 - EigenTrust, TNA-SL (Trusted Network Analysis with Subjective Logic), ...
 - Little or no comparison between them
 - Designed and implemented a framework for comparative evaluation of reputation systems
 - Identified evaluation criteria
 - Generation of evaluation scenarios
 - Development of malicious strategies
 - Collection of statistics and analysis











Dynamic IP Reputation from DNS

Georgia Tech

- Dynamic Domain Name reputation using passive DNS (pDNS)
 - Professional DNS hosting differs from non-professional
 - pDNS information is already present in our network
 - Static IP/DNS blacklists have limitations
 - Malicious Users tend to reuse their infrastructure
- Contributions:
 - Zone and network based clustering of pDNS
 - A new method of assigning reputation on new RRSETs using limited {White/Grey/Black}-listing
 - A dynamic Domain Name reputation rating system
 - Always maintain fresh reputation knowledge based on pDNS

Spatio-Temporal Reputation

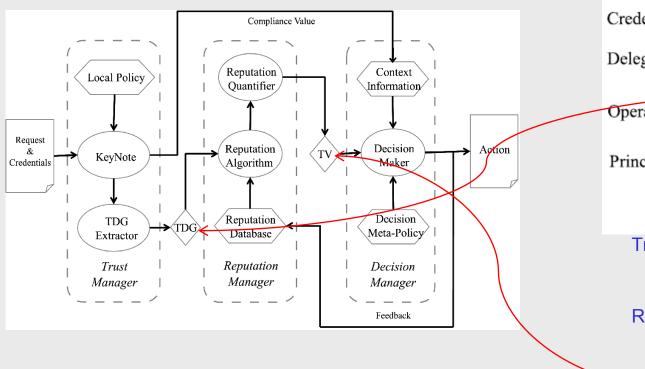
(Penn + Georgia Tech)

- As the RM part of QTM, we have developed reputation-bases trust management based on spatiotemporal reputation
- Approach
 - Assumptions
 - Bad guys are geographically clustered (spatio)
 - Bad guys are likely to repeat bad behaviors (temporal)
 - Given
 - A historical record of those principals known to be bad, and the time when this was noted (feedback)
 - Produce
 - An extended list of principals who are thought to be bad at the current time, based on their own past history, and the history of those around them
- Case studies: Spam filter based on IP blacklist, wikipedia



Quantitative Trust Management (QTM)

- QTM provides a dynamic interpretation of authorization policies for access control decisions using evolving reputations of parties
- QuanTM is a QTM system that combines elements from PTM and RTM to create a novel method for trust evaluation



> Trust Dependency Graph (TDG), encoding PTM relationships useful for RTM

Reputations of PRINCIPALS,
DELEGATIONS and
CREDENTIALS are
aggregated

The QuanTM Architecture

